

RESEARCH TREND OF NANOMATERIALS IN BIOMEDICAL APPLICATION: A BIBLIOMETRIC STUDY OF PLANT-DERIVED NANOMATERIALS AS CANCER TREATMENT

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ABSTRACT

Plant-derived nanomaterials (PDNM) have gained significant attention recently due to their potential pharmacological applications against cancer disease. Plant-derived natural compounds are significant resources for the discovery of potential anticancer drugs due to their unique properties, including their small size, high surface area, and ability to penetrate biological barriers. While research in the plant-based anticancer field has surged in recent years, systematic bibliometric analyses covering a longer period and containing up-to-date publications remain scarce. In this study, efforts are being made to measure plant nanomaterial research, especially as cancer treatment output published in the form of scholarly literature. The data, for the period of 2020-2026, were extracted from the Scopus abstract and citation database and analyzed by using bibliometric techniques. Our findings showed that the number of plant anticancer-related publications underwent an accelerating growth from 2020-2026. The primary publications were domains of biochemistry genetics and molecular biology, pharmacology, toxicology and pharmaceuticals, medicine, and chemistry. Additionally, we noted that plants as natural resources have a big potential as cancer therapy and these innovative plant-based nanomaterial systems may be a promising contender for various pharmacological applications based on the many research reports (10.318 documents) that discuss on the influence of plants as cancer therapy agents. There are 5 clusters publication sources are molecules, international journal of molecular and science, journal ethnopharmacol, international journal of biology macromolecular, and food chemicals and the most frequently cited journals in international journal of molecular, molecules, frontiers pharmacology, international journal of biology, and pharmaceuticals. Our study provides new insights into the progress and trends in the plant anticancer field and will assist researchers in grasping the future research direction.

Keywords: Plant, Nanomaterial, Cancer, Scopus, Bibliometric study.

INTRODUCTION

Cancer has been a constant battle globally with a lot of development in cures and preventative therapies. The disease is characterized by cells in the human body continually multiplying with the inability to be controlled or stopped. Consequently, tumors of malignant cells with the potential to be metastatic^(1, 2). Forecasts from the International Agency for Research on Cancer (IARC), predict 30.2 million new cancer cases globally by 2040, leading to 16.3 million fatalities. Such projections hinder the realization of Sustainable Development Goal 3 (SDG3) which aspires to ensure healthy lives and promote well-being for all at all ages^(3, 4). Current treatments include chemotherapy, radiotherapy and chemically derived drugs. Treatments such as chemotherapy can put patients under a lot of strain and further damage their health. Traditional cancer treatments, including surgical excision, chemotherapy, and radiotherapy, usually have great side effects on patients⁽⁵⁾. However, the advent of precision medicine, such as targeted therapy and immunotherapy, has revolutionized cancer care by enhancing treatment efficacy and minimizing adverse effects.

Plant-derived natural compounds serve as crucial sources for new drug development and play a vital role in primary healthcare and overall well-being. For many years herbal medicines have been used and are still used in developing countries as the primary source of medical treatment. Plants have been used in medicine for their natural antiseptic properties. Medicinal plants have been used for thousands of years in folk medicines in Asian and African populations and many plants are consumed for their health benefits in developed nations. According to the World Health Organization (WHO) some nations still rely on plant-based treatment as their main source of medicine and developing nations are utilizing the benefits of naturally sourced compounds for therapeutic purposes^(1, 3). Thus, research has developed into investigating the potential properties and uses of terrestrial plants extracts for the preparation of potential nanomaterial-based drugs for diseases including cancer⁽⁶⁾. Many plant species are already being used to treat or prevent development of cancer. However, the intricate chemical compositions of natural products make the exploration of anticancer drugs a formidable challenge. For example, out of 35,000 species screened by the National Cancer Institute (NCI) for bioactivity both in vitro and in vivo, only two drug structures - paclitaxel and camptothecin - were identified⁽⁷⁾. To explore effective anticancer compounds among numerous natural products, increasing research focused on target plant search, bioactive compound isolation, and molecular pathway clarification, combined with multidisciplinary approaches^(8, 9).

Plants can produce a large type of typical nanostructures as matching with the current material (nanostructure) produced by the synthetic, engineered process⁽¹⁰⁾. Plant-derived drugs are desired for anticancer treatment as they are natural and readily available. They can be readily administered orally as part of patient's dietary intake⁽¹¹⁾. Also, being naturally derived compounds from plants are generally more tolerated and non-toxic to normal human cells^(11, 12). With advancements and discoveries in naturally derived drugs new technologies are emerging for the application and dosage of these anticancer compounds. Administration of new drugs needs to be effective for the compound to be a successful alternative to current treatments such as chemotherapy. Through the field of nanotechnology the use of nanoparticles (NPs), as a delivery system for drugs to reach target sites, is developing⁽¹³⁾. Fueled by the advances in biotechnology and materials science, nanotechnologies have been widely investigated for cancer treatment, aiming to enhance safety, accuracy, and efficacy by leveraging the unique properties of engineered nanomaterials. Additionally, Plant-derived nanovesicles (PDNVs) derived from natural green products represent an innovative biomaterial with high biocompatibility for fighting against cancer. By taking advantage of the enhanced permeability and retention (EPR) effect that is a pathophysiological phenomenon of solid tumor vasculature caused by defects in vascular structure, gaps between vascular endothelial cells, abundant vascular mediators and impaired lymphatic recovery, leading to preferential filtration and permeation of nano-sized materials (10e100 nm) within tumors⁽¹⁴⁾.

This article aims to take a bibliometric study of current nanomaterials derived by natural compounds that have anticancer therapeutic properties and their developments in the field. In this study, to provide a comprehensive insight into the research developments and future trends of plant-anticancer compounds, we applied the Vosviewer platform to analyze 10,318 publications in the field over the past 5 years (2020-beginning 2026) based on the bibliometric framework.

MATERIAL AND METHODS

Literature search strategy

Scopus based data, an authoritative and international database offering comprehensive information on each publication, was selected as the bibliometric database to obtain the literature search results. The boolean formula we used in this study was: "Plant" OR "Nanomaterial" OR "Plant-Derived

Nanomaterial” AND “Anticancer” OR “Cancer therapy”. The collection of literature records was through the open refine file format was applied to sort the full information of each record for data cleaning and processing. We obtained 10.318 documents. We further filtered non-English, subject area, and a total of 5000 records were used for bibliometric analysis.

Bibliometric analysis

In this study, we used classic bibliometric methods that were divided into four steps. The first step is literature collection. We searched related literature around the topic of plant-anticancer compounds using the strategy mentioned before. For the data cleaning step, we use openrefine tools by consolidating multiple terms with identical meanings into a single keyword. During the data processing step, we classify the information of all literature, e.g., keywords, year of publication, journal, countries, co-cited literature, etc. The classified information was performed for statistical analysis and visualization. In the last step, we summarized the statistical results to reveal the research status, hotspots, and future trends.

RESULTS AND DISCUSSION

There were approximately 10.318 related articles published in the plant-anticancer field from 2020-2025 globally. The number of publications in this field displayed a rapidly increasing trend during 2020-2024 (Fig. 1). 1527 paper numbers were published as early as 2020. After a development of nearly five years, the annual number of publications exceeded 2.158 in 2024. Up to 2025, the number of one-year publications decreased to 1.433 documents. The exponential increases in global publication output showed the rapid growth of the plant-anticancer field and the enormous potential of plant-derived compounds in anticancer in the future.

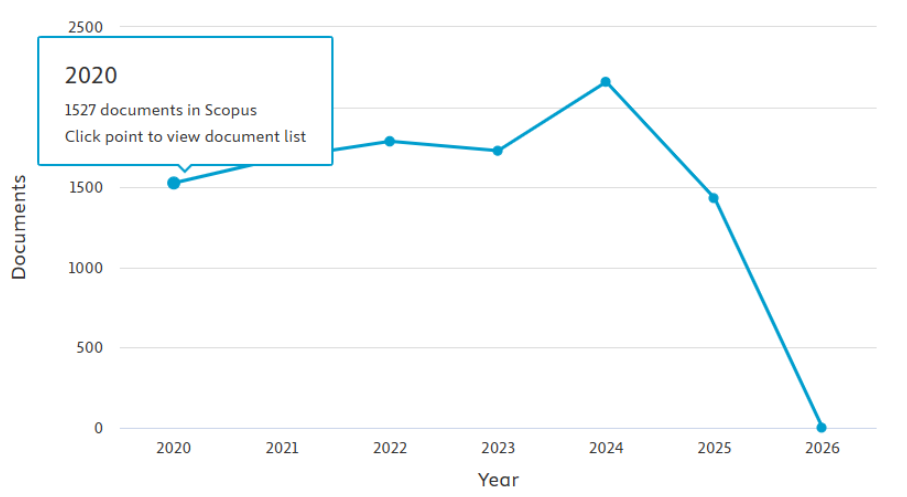


Figure 1. Summarized of Plant nanomaterial in anticancer applications research documents by year in Scopus around 2020-2026

Documents play a crucial role in every stage of research development. As written evidence, documents serve to record the ideas, methodology, results, and analysis conducted by researchers, ensuring their scientific validity. Through proper documentation, research can be reviewed, replicated, and developed by others, thus promoting the continuity of knowledge. As shown at fig. 2 the most type of document related to plant nanomaterial in anticancer applications goes to article type 66.1%, review type 29.8%, and book chapter 2.7%.

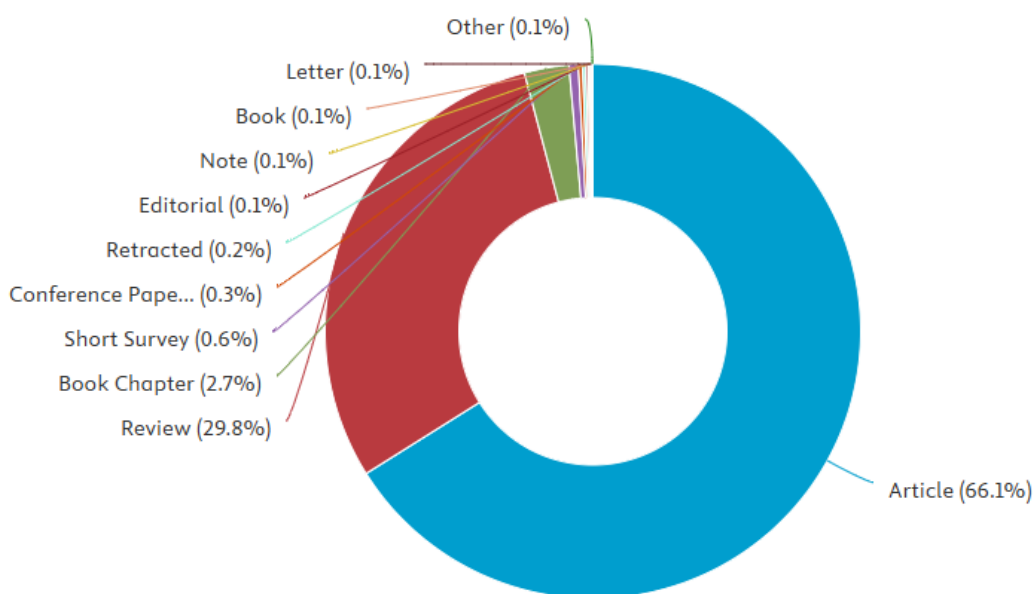


Figure 2. Summarized of Plant nanomaterial in anticancer applications research documents by type in Scopus around 2020-2026

The step towards development of cancer involves alterations of epigenetic processes and their deregulation. As shown at fig. 2 the most subject area of document related to plant nanomaterial in anticancer applications goes to biochemistry genetics and molecular biology 23.0%, pharmacology, toxicology and pharmaceutics 22.6%, medicine 15.4%, and chemistry 11.5%.

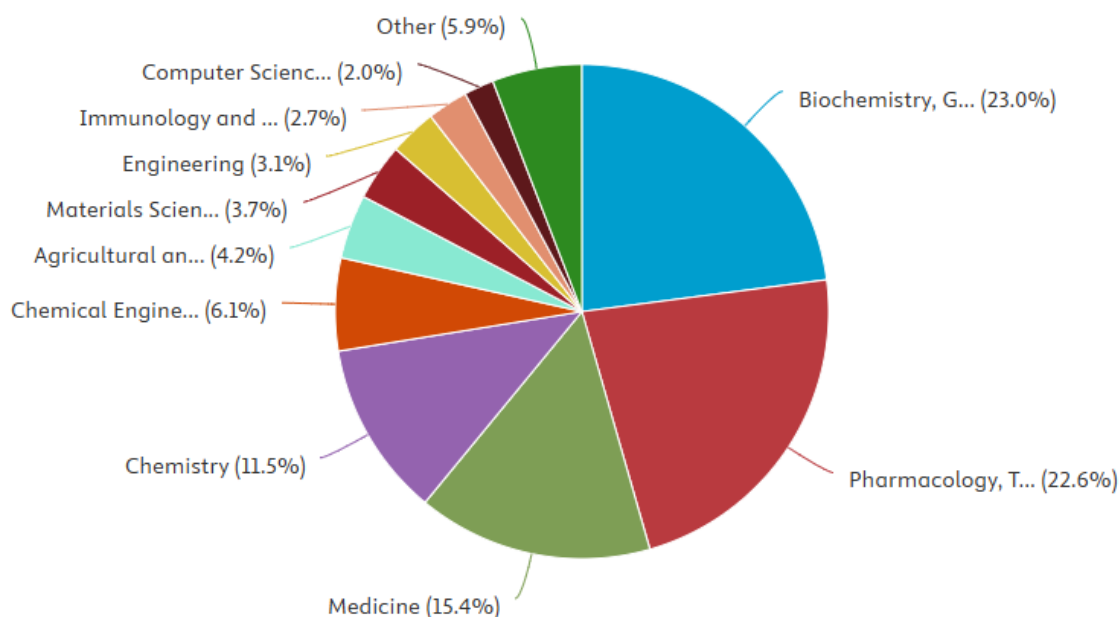


Figure 3. Summarized of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026

To measure the cooperation situation among different countries/territories, we established the bibliographic coupling by country⁽¹⁴⁾ as shown in Fig. 4 It revealed extensive cooperation between these countries in plant-anticancer reaches, 86 items 8 cluster which is particularly evident in productive countries, e.g., India, Saudi Arabia, South Korea, Indonesia, Egypt, and Iran.

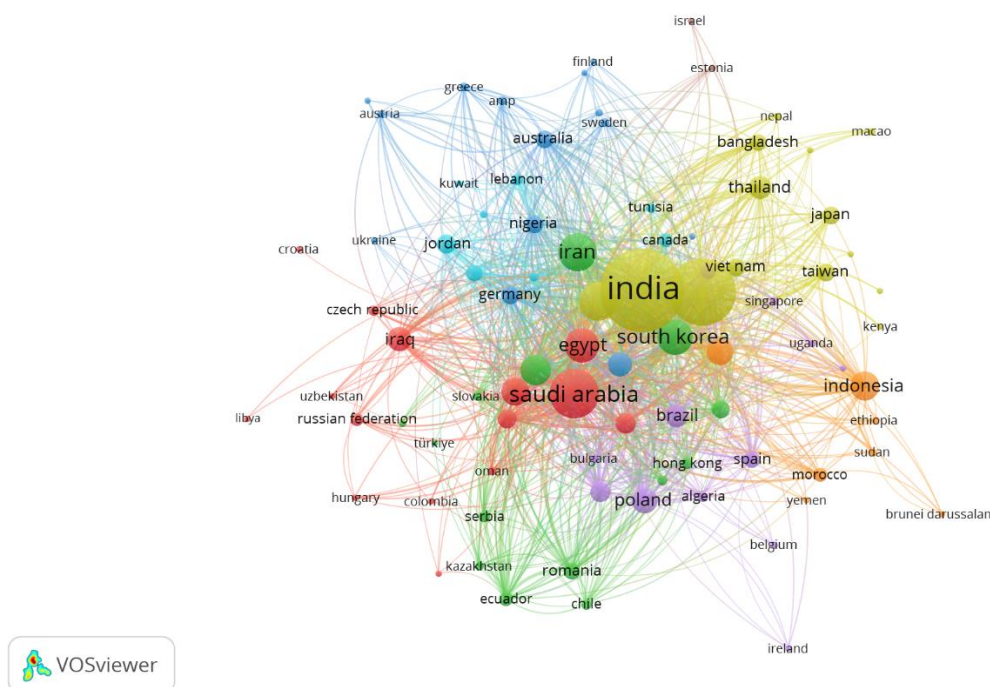


Figure 4. Bibliographic coupling by country of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026.

Cross-border research collaboration, reflected through country-by-country co-authorship, plays a strategic role in improving the quality and impact of scientific publications. The involvement of authors from different countries not only broadens the perspectives and expertise of those involved but also enriches the resulting methodology, data, and analysis. We also explored the contribution of co-authorship by country in plant-anticancer research in terms of Fig. 5, the most productive co-authorship by country are India, China, United state, Saudi Arabia, ad Iran.

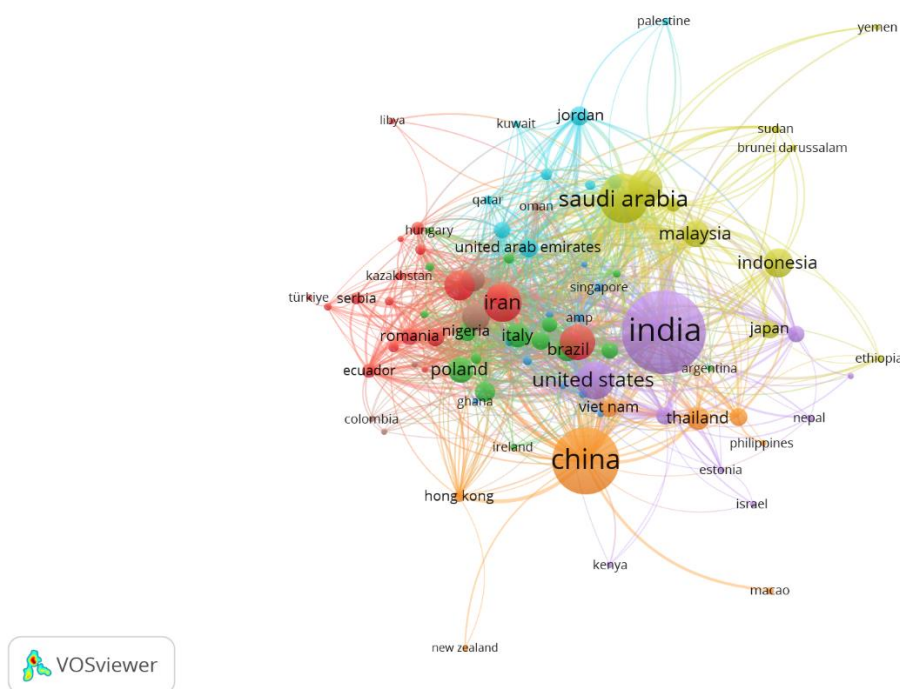


Figure 5. Bibliographic coupling by country of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026.

Citation analysis is regarded as one of the most important approaches to assess the impact or reflecting the recognition of an article. The analysis of top-cited articles can help reveal the research topics that have received the most attention from the scientific community. The co-citation relationship is formed when two journals were cited together in the same publication. Performing the co-citation analysis can measure the frequency of jointly cited journals, visualize the diversity of publication sources, as well as identify disciplines that is involved in a specific journal. The density visualization of co-citation network of Plant nanomaterial in anticancer applications was generated by Vosviewer and shown in Fig. 6a. There are 1000 items divided into 5 clusters publication sources are molecules, international journal of molecular and science, journal ethnopharmacol, international journal of biology macromolecular, and food chemicals. The circle size and intensity are proportional to citation times, according to the software instruction. Same color is suggestive of similar or cross-linked field. As indicated, the most frequently cited journals in international journal of molecular, molecules, frontiers pharmacology, internationa journal of biology, and pharmaceuticlas as shown in fugire 6b. By taking a closer look at the research field associated with the cited sources, it is obvious that the research shows a cross-disciplinary feature, with a focus on biochemistry genetics and molecular biology, pharmacology, toxicology and pharmaceutics, medicine, and chemistry.

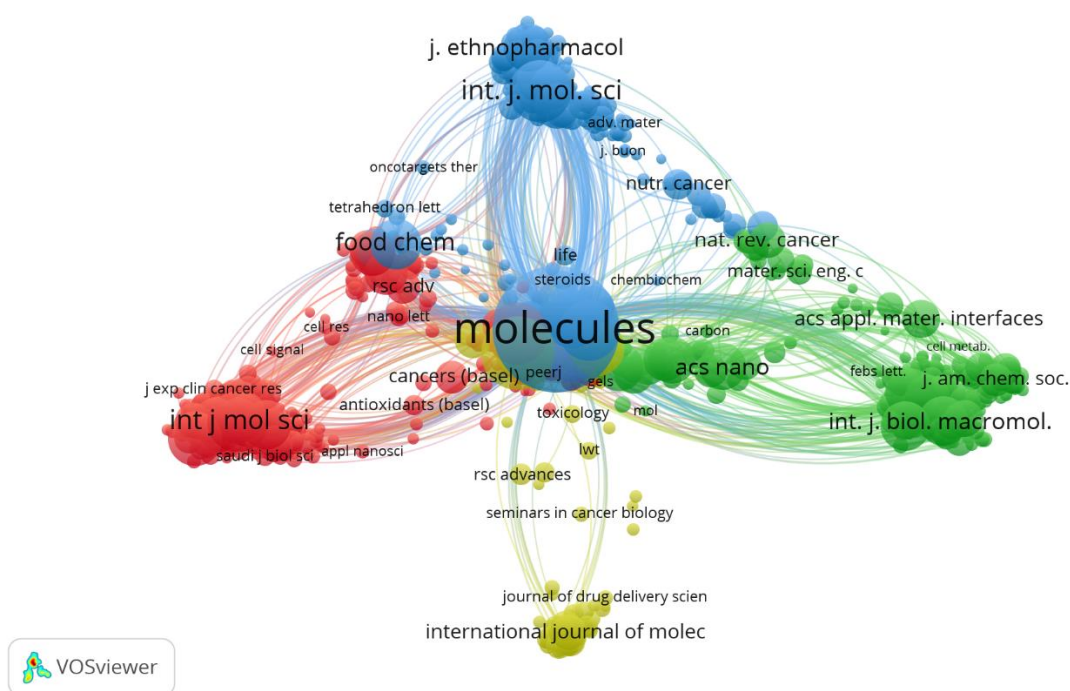


Figure 6a. Co-citation by source of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026.

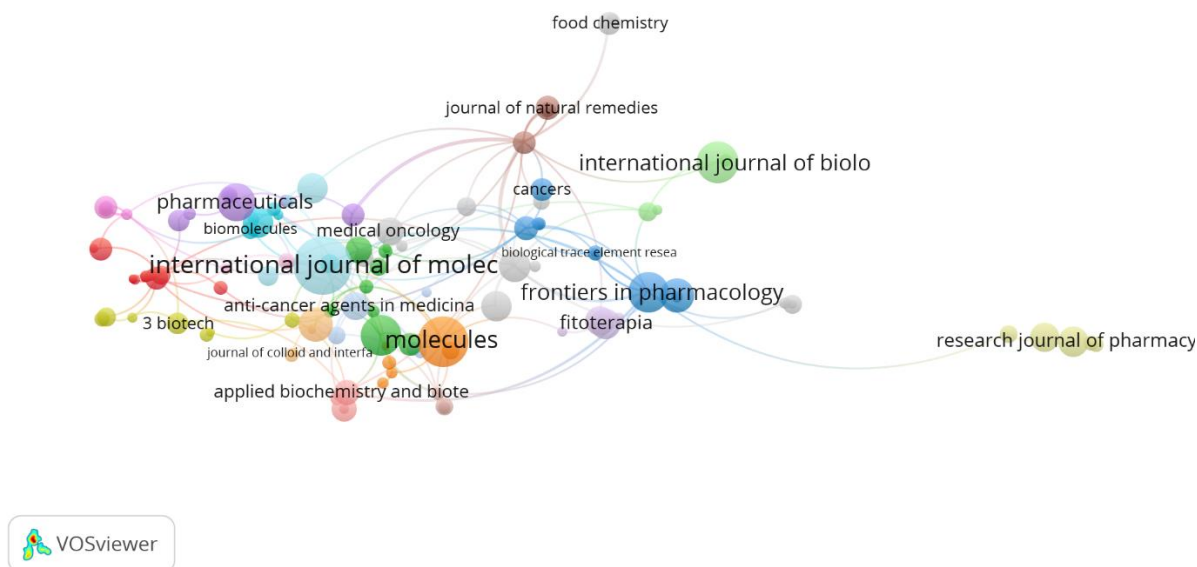


Figure 6b. Citation by source of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026.



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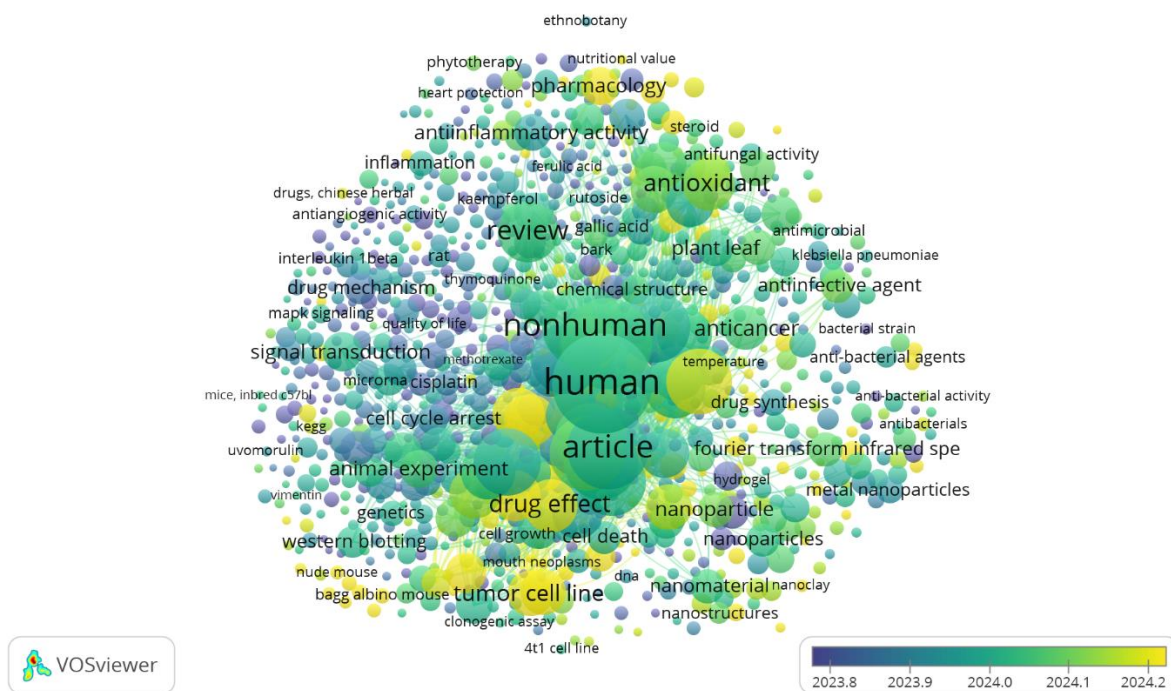


Figure 7b. Co-occurrence by Keyword of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026.

Additionally, we performed a co-occurrence by keyword analysis to identify emerging research themes in the field of plant nanomaterial as cancer treatment around 2020-2026. As shown at fig. 7 the keyword co-occurrence overlay map visualizes 1,000 keywords organized into 5 major thematic clusters: the most frequent keyword, human, drug effect, antioxidant, plant leaf, anticancer. While informative, Fig. 7b is a derivative of Fig. 7a, which provides an opportunity to visualize the chronological trend of keyword evolution over time in Plant nanomaterial in anticancer applications research. As indicated, terms marked with purple indicate their average year of publication in early era, and green color denotes that the keywords have been continuously used. For example, keywords such as hydrogel and antiangiogenic were frequently used around 2020, while human experiments, antioxidant, animal experiment, plant leaf, and drug effects seem to be continuously popular choices. In addition, light green and bright yellow color represent “trendy” research directions, were tumor cell line, temperature, nanostructure reaction are identified as great interests. Therefore, the inclusion of time factor provides a simplified but helpful approach to recognize the research directions as exemplified in the cases of cancer treatment.

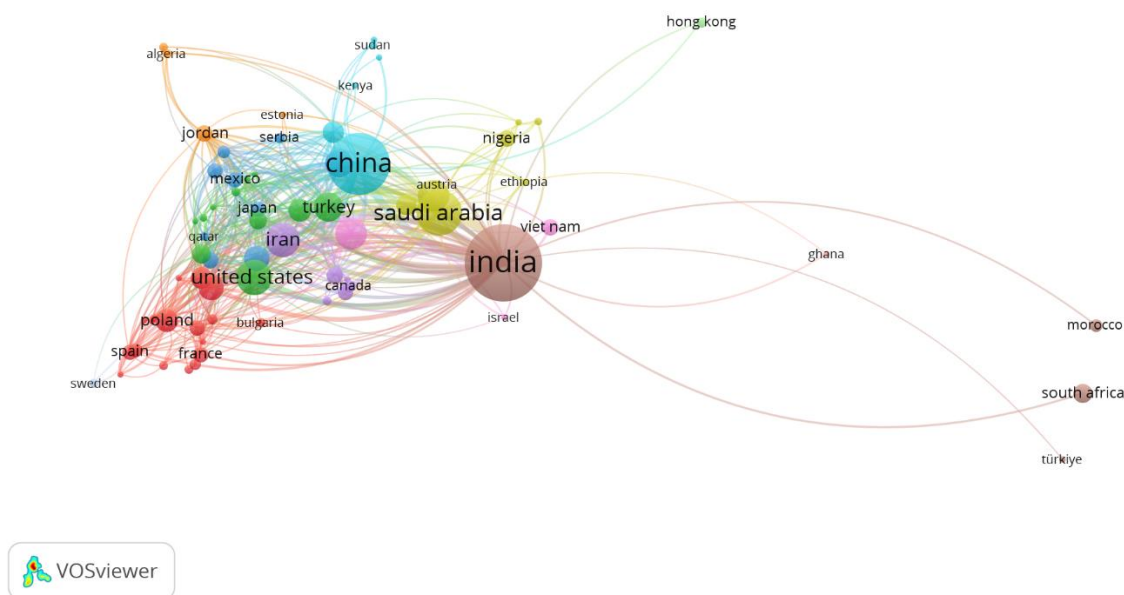


Figure 8. Citation by country of Plant nanomaterial in anticancer applications research documents by subject area in Scopus around 2020-2026.

Citation analysis is regarded as one of the most important approaches to assess the impact or reflect the recognition of an article. The analysis of top-cited articles can help reveal the research topics that have received the most attentions from the scientific community⁽¹⁵⁾. The analysis was also made to know the citations received by the plant nanomaterial as cancer treatment articles along with the cited rate. Fig 8 highlights that plant-nanomaterial as cancer treatment articles published during 2020-2026 have been cited by 72 countries. This step determines which countries are most frequently cited in the context of plant nanomaterials as cancer treatment. The 5 countries with the highest citation strength are India, China, Saudi Arabia, United State, and Iran. The exploration of plant nanomaterial as cancer treatment is such an important research direction as it may not only advance the development of cutting-edge nanotechnology, but also help to revolutionize biotechnology process with an aim for improving human well-being.

DISCUSSION

These systems accumulated rich resources of medicinal plants, plant species believed to possess medicinal propertie especially in anticancer activities, creating an expansive pool for the exploration, screening, and application of anticancer drugs. Plant-derived drugs can fall under four classes of drugs with the following activities: methytransferase inhibitors, DNA damage preventive drugs or antioxidants, histone deacetylases (HDAC) inhibitors and mitotic disruptors⁽¹¹⁾. Compounds including sulforaphane, isothiocyanates, isoflavones and pomiferin are HDAC inhibitors. They inhibit the activity of carcinogenic proteins. For example, sulforaphane has shown to inhibit important targets in breast cancer proliferation. Decreased expression of ER, EGFR and HER-2 resulted from HDAC inhibition by sulforaphane treatment in breast cancer cell lines. In cancer cells, epigenetically silenced genes which are functional for chromatin acetylation are reactivated by HDAC inhibitors and cancer cells are then able to enter programmed cell death (apoptosis). Plant-derived compounds which show inhibition of HDAC can *Plant Nanomater J.*, 1(1), 1-10 (2025)

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enhance chemotherapeutic sensitivity in human cancers⁽¹⁶⁾. Moreover, more new plant species in the same taxonomic group of these documented anticancer plants could further explore their natural compounds with anticancer activities because of closely related plant species usually with some similar phytochemicals⁽³⁾. Such profound accumulation made anticancer drugs developed based on these traditional medicinal plants safer and easier to accept and promote. Therefore, traditional medicine is significant to the exploration of plant natural compounds in the anticancer field.

Furthermore, nanomaterials contain many different bioactive molecules, which have been demonstrated to reduce the risk of carcinogenesis and hold an antitumor effect. These substances are inextricably linked to the plants that they are derived from. Different plants contain a variety of different phytochemicals, many of which are their derived analogs, such as curcumin, gingerol, gallic acid, tannins, and others, and have been identified to have the potential of cancer treatment. Therefore, these substances can be used as anticancer therapeutics by targeting a variety of cancer cell signaling pathways, inhibiting cancer cell activating proteins and enzymes, promoting apoptosis, inducing cell cycle arrest, and regulating antioxidant status.

Our finding revealed that the publication contribution in the plant anticancer field was closely related to the development of traditional medicine in corresponding countries. Conventionally, a country's research publication output aligns with its research and development (R&D) expenditures. In addition, mechanism publications usually could reveal the complex regulatory process of drugs in vivo at the molecular level, providing theoretical support for anticancer medicine exploration. Thus, these studies were also important for the output evaluation of each country. We have found that countries with an increase in innovation performance over the past years mostly experienced higher economic growth. Countries with higher research and development expenditures have not only more researchers, but also more patents registration.

FUTURE AND CHALLENGING

Nevertheless, it is still a challenge to fully develop the advantages of traditional medicine in cancer treatment limited by the existing technology. Traditional medicines often contain complex plant metabolites in cancer therapy, and the synergy of these metabolites helps traditional medicines achieve a significant therapeutic effect. At present, in the plant anticancer field, researchers generally focus on individual plant compounds purified from mixtures for mechanism analyses and drug developments. The study of the synergistic effect between complex metabolites of plants is still a challenge to be overcome in future research.

CONCLUSION

Plant-derived natural compounds play a pivotal role in the quest for high-efficiency and low-toxicity drugs. Plant-derived NPs are of significant use in the medicinal field, having biomedical applications. These NPs have a convenient shape and size and can be used for non-toxic and efficient drug delivery, anticancer treatment. Given the surge in related global research, we conducted a comprehensive bibliometric analysis of literature in the plant anticancer domain spanning 2020-2026. Our findings underscored the burgeoning interest in plant anticancer studies, with 10,318 publications recorded. Distinctly, countries and institutions with deep roots in traditional medicine emerged as significant contributors to literature. We also analyzed the contributions of different countries and institutions in the field and revealed that traditional medicine promoted the outputs of plant anticancer related publications. In addition, the most influential authors and publications were explored for tracking related research. Furthermore, the analyses of historical and current research fields showed accelerating growth in Pharmacology & Pharmacy field and Biochemistry & Molecular Biology field.

CONFLICT OF INTERESTS

The authors declare no conflict of interests related to the publication of this paper.

REFERENCES

1. Greenwell M, Rahman PK. Medicinal Plants: Their Use in Anticancer Treatment. *Int J Pharm Sci Res.* 2015;6(10):4103-12.
2. Ochwang'i DO, Kimwele CN, Oduma JA, Gathumbi PK, Mbaria JM, Kiama SG. Medicinal plants used in treatment and management of cancer in Kakamega County, Kenya. *J Ethnopharmacol.* 2014;151(3):1040-55.
3. Wang M, Li Y, Pan T, Jia N. Plant natural compounds in the cancer treatment: A systematic bibliometric analysis. *Heliyon.* 2024;10(14):e34462.
4. Bray F, Laversanne M, Weiderpass E, Soerjomataram I. The ever-increasing importance of cancer as a leading cause of premature death worldwide. *Cancer.* 2021;127(16):3029-30.
5. Halabi MF, Sheikh BY. Anti-proliferative effect and phytochemical analysis of *Cymbopogon citratus* extract. *Biomed Res Int.* 2014;2014:906239.
6. Sivaraj R, Rahman PK, Rajiv P, Narendhran S, Venckatesh R. Biosynthesis and characterization of *Acalypha indica* mediated copper oxide nanoparticles and evaluation of its antimicrobial and anticancer activity. *Spectrochim Acta A Mol Biomol Spectrosc.* 2014;129:255-8.
7. Li D, Jia N, Huang H, Chen S, Dou Y, He X, et al. Helium ion irradiation enhanced precipitation and the impact on cavity formation in a HfNbZrTi refractory high entropy alloy. *Journal of Nuclear Materials.* 2021;552:153023.
8. Mangal N, Erridge S, Habib N, Sadanandam A, Reebye V, Sodergren MH. Cannabinoids in the landscape of cancer. *J Cancer Res Clin Oncol.* 2021;147(9):2507-34.
9. Ghanbari-Movahed M, Kaceli T, Mondal A, Farzaei MH, Bishayee A. Recent Advances in Improved Anticancer Efficacies of Camptothecin Nano-Formulations: A Systematic Review. *Biomedicines.* 2021;9(5).
10. Trivedi R, Upadhyay TK, Mujahid MH, Khan F, Pandey P, Sharangi AB, et al. Recent Advancements in Plant-Derived Nanomaterials Research for Biomedical Applications. *Processes [Internet].* 2022; 10(2).
11. Solowey E, Lichtenstein M, Sallon S, Paavilainen H, Solowey E, Lorberboum-Galski H. Evaluating medicinal plants for anticancer activity. *ScientificWorldJournal.* 2014;2014:721402.
12. Okeke ES, Nweze EJ, Anaduaka EG, Okoye CO, Anosike CA, Joshua PE, et al. Plant-derived nanomaterials (PDNM): a review on pharmacological potentials against pathogenic microbes, antimicrobial resistance (AMR) and some metabolic diseases. *3 Biotech.* 2023;13(9):291.
13. M A, S KB, Liyana EP, Jasmine JS. Transformative potential of plant-based nanoparticles in cancer diagnosis and treatment: bridging traditional medicine and modern therapy. *Naunyn-Schmiedeberg's Archives of Pharmacology.* 2025.
14. Chauhan SK. Nanotechnology research output: bibliometric analysis with special reference to India. *Journal of Nanoparticle Research.* 2020;22(9):278.
15. Zhu S, Meng H, Gu Z, Zhao Y. Research trend of nanoscience and nanotechnology – A bibliometric analysis of *Nano Today.* 2021;39:101233.
16. Jyoti K, Kaur K, Pandey RS, Jain UK, Chandra R, Madan J. Inhalable nanostructured lipid particles of 9-bromo-noscapine, a tubulin-binding cytotoxic agent: in vitro and in vivo studies. *J Colloid Interface Sci.* 2015;445:219-30.